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Can environmental centralization help reduce pollution? Evidence from an administrative reform in China

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ABSTRACT

Amid the longstanding dispute over the centralization and decentralization of environmental regimes, most discussions have focused on developed countries. Few studies have tested the mechanisms underlying centralization and decentralization. The establishment of the Ministry of Environmental Protection in China in 2008 has led to various changes in the degree of environmental centralization. Based on this reform, we use standard and continuous difference-in-difference designs to estimate the effect of environmental centralization on pollution in developing countries and to test the underlying mechanisms. We find that the establishment of the Ministry of Environmental Protection has effectively led to reduced pollution in provinces with higher degrees of environmental decentralization. Furthermore, centralization has restricted local governments' free riding and reduced emissions at the borders. It has also strengthened local governments' incentives for environmental governance. The implication is that environmental centralization is conducive to reducing the free-riding behavior and race-to-the-bottom problems of developing economies, thus contributing to environmental well-being.

1. Introduction

Although the Chinese economy has entered a stage of stable development, China's environmental problems have become increasingly prominent. According to the China Development Index¹ issued by the National Survey Research Center at Renmin University of China in 2018, the social environment sub-index has the slowest growth rate and even shows a slight negative growth trend. In addition, the *2018 Environmental Performance Index Report* released by Yale University shows that China's air quality ranks fourth from the bottom, only surpassing that of India, Bangladesh, and Nepal. This makes China one of the countries with the most serious air pollution problems in the world. Various environmental policies have recently been proposed by governments at different levels in China, but these policies have yet to contribute to effective environmental protection. Two questions thus arise. First, does the inefficiency of environmental policies in developing countries, such as China, stem from incentive distortions under environmental decentralization? Second, is environmental centralization more suitable?

The decentralization versus centralization debate is at the core of the topic of environmental federalism. Decentralization refers to the transfer of public power and service responsibilities from the central government to local governments (Vo, 2010). The differences between environmental decentralization and centralization and their possible effects have been discussed in the literature. The centralization system is supported for the following reasons. Environmental decentralization is ineffective due to cross-regional environmental spillovers (Chen et al., 2019; Du et al., 2020). In the context of decentralization, the free-riding behavior is common in local governments. That means, significantly more pollutants are emitted outside the administrative area than inside the administrative area (Gray and Ronald, 2004; Lipscomb and Mobarak, 2017). Another reason for widespread concern is horizontal competition among locals. The asymmetric incentives of the economy and the environment have led local officials to naturally prioritize economic development over environmental well-being. Therefore, local officials have a strong incentive to set lax environmental regulations and invalidate local environmental governance, indicating a race to the bottom among locals (Sigman, 2014; Hong et al., 2019). Finally, the collusion between local governments and firms cannot be ignored (Ghanem and Zhang, 2014; Kamp et al., 2017). Environmental

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[1] The China Development Index was surveyed and published by Renmin University of China. It includes a general index and four sub-indices (on health, education, living standards, and social environment).

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monitoring offers an example. To fulfill economic interests, lower levels of government that are afforded the right to monitor tend to manipulate pollution data to help firms pass inspections. Thus, decentralization is generally a sub-optimal choice compared with centralization (Kunce and Shogren, 2005, 2007).

Although the spillover effect is undeniable, we should take a more neutral attitude because when the spillover effect of pollution is small, the centralized system becomes detrimental to overall welfare (Huang et al., 2018). In addition to the spillover effect of pollution, heterogeneities between regions exist. This is the main reason for support for decentralization. Due to the heterogeneity in geographical conditions, self-purification capabilities, residents' environmental concerns, and regional economic development, local governments can formulate more appropriate environmental regulations for their regions than the central government (Falleth, 2009; Li and Chen, 2018). That is, uniform environmental regulations may have completely different effects across regions due to regional differences (Chen et al., 2018). Hence, investigating the effects of environmental centralization and decentralization on environmental outcomes remains a controversial issue that has been rarely discussed in the context of developing countries (Sjöberg and Xu, 2018; Evans and Stafford, 2019).

An inherent empirical challenge to identifying the impact of environmental decentralization on pollution is that doing so must address two important issues. First, reverse causality may exist between environmental decentralization and pollution. As explained above, environmental decentralization has an important impact on pollution. However, pollution may also affect the degree of environmental decentralization or centralization. To avoid this complication, we use a quasi-natural experiment in China to estimate the impact of environmental centralization on pollution. In 2008, the Environmental Protection Agency (EPA) was upgraded to the Ministry of Environmental Protection (MEP) in China (Section 2 provides more detail). The MEP is part of the State Council. Departments are the implementers of government functions. As the establishment of departments determines how government power is exercised, changes to the establishment of departments imply changes to the power distribution. This administrative reform in China thus provides a unique opportunity to use a difference-in-difference (DiD) design to identify the impact of environmental decentralization on pollution.

Second, how the degree of environmental decentralization should be measured remains controversial. According to Zhang et al. (2011), fiscal decentralization is very similar to environmental decentralization. But fiscal decentralization focuses on the economy rather than on the environment. Based on the logic of the environmental governance of governments, the number of staff in environmental protection departments is a more suitable measure of the degree of environmental decentralization (Qi et al., 2014). Environmental protection departments and their staff are the main carriers of environmental protection functions. Therefore, the proportions of environmental protection department staff at different levels of government can reflect the allocation of power. The results show that the environmental decentralization indicators (EDI) for the eastern and central regions during 2008–2015 (i.e., after the establishment of the MEP) decreased by an average of 7.15% and 4.48%, respectively, from their 2001 to 2007 levels. Thus, this reform has had different effects on various regions.

Based on China's provincial panel data from 2001 to 2015, we use standard and continuous DiD designs to estimate the effect on pollution of the establishment of the MEP, which represents the decrease in the degree of environmental decentralization. The results show that environmental centralization can significantly reduce pollution by 15% and 19.5% under the standard and continuous DiD designs, respectively.

We also investigate the potential mechanisms through which the establishment of the MEP affects pollution. First, the establishment of the MEP has helped control transboundary pollution (Sjöberg and Xu, 2018; Dedoussi, 2020). Pollution in an upstream area spreads downstream, which tends to cause cross-regional pollution disputes (Cai et al., 2016b; Chen et al., 2016). Since the establishment of the MEP, coordinated governance of the entire river basin has been promoted. Adjacent areas have also been united such that they no longer conduct pollution control individually.

Second, environmental centralization regimes offer pollution control incentives to local governments (Hong et al., 2019). The establishment of the MEP has allowed the central government to obtain more accurate monitoring data, and environmental quality has become one of the decisive factors in the promotion of local officials (Kahn et al., 2015; Chen et al., 2016). When local officials face environmental assessments, the strategies for hiding pollution used in the past become ineffective, and working to improve the environment is the best option (Zhang et al., 2018).

We make three main contributions to the literature. First, this study complements the research on environmental federalism in developing countries. With the exception of India (Duflo et al., 2018; Du et al., 2020), most studies have discussed environmental federalism in developed countries (Sigman, 2014; Lipcomb and Mobarak, 2017). However, this issue is of greater value to developing countries because their economies are in greater conflict with the environment. This study is based in China, the world's largest developing country.

Second, two-way causality is a widespread concern in estimating the environmental output of centralization or decentralization and may contaminate the results. We circumvent this problem by using an administrative reform in China, namely the establishment of the MEP (Cai et al., 2016b).

Third, few studies have verified the mechanisms through which environmental centralization affects pollution (Ran et al., 2020). We fill this research gap, finding that environmental centralization alleviates cross-regional pollution problems and strengthens the efforts of local governments.

The remainder of this paper proceeds as follows. Section 2 provides an overview of the establishment of the MEP and analyzes its potential influence mechanisms. Section 3 discusses the data and estimation strategy. Section 4 tests whether the establishment of the MEP affects pollution. Section 5 empirically examines the mechanisms. Finally, Section 6 offers concluding remarks.

2. Background and theoretical mechanisms

2.1. Background: establishment of the MEP

In the 1980s, the Environmental Protection Leading Group (EPLG) was established. It was an informal department with no administrative hierarchy. The EPLG lacked the theoretical and technical foundation for national environmental affairs. It could hardly play a role in environmental management. In 1988, the EPA was born. It was an independent department and secured a much higher administrative level. However, under the financial contracting system at that time, the fiscal revenue of the central government continued to decrease,[2] weakening the central government's coordination and environmental supervision capabilities. To prevent further environmental deterioration, the EPA was upgraded to the MEP and became a part of the State Council in 2008. Fig. 1 illustrates this evolution.

The 2008 reform has expanded the scope with which the MEP can perform its duties and has facilitated the central government's intervention in local environmental affairs (Qi, 2008). In general, the

[2] The central government's share of the total national fiscal revenue decreased from approximately 40% in 1984 to approximately 20% in 1993. This situation was not alleviated until 1994 after the tax-sharing system reform.

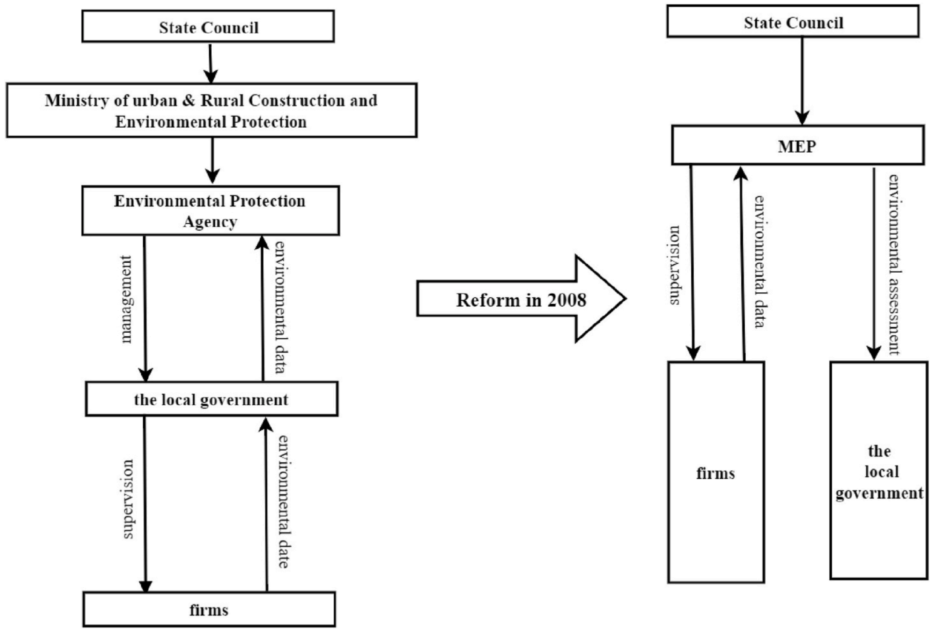

Fig. 1. Environmental institutional reform in 2008.

financial support and management functions of the MEP have been significantly strengthened. From a financial perspective, the central government's environmental protection expenditure has increased significantly,[3] and its supervision has become stricter. From the perspective of management functions, the central government's ability to handle cross-regional disputes and environmental supervision has been significantly enhanced. A trans-regional ecological compensation mechanism has been established to deal with transboundary pollution.[4] A pollutant emission control department and an environmental monitoring department have been added to undertake pollution control and monitoring, respectively. The promotion of local officials now adopts a "one-vote veto" system.[5] As a result, economic growth is no longer the only criterion stimulating local officials' environmental protection motives for promotion.

2.2. Theoretical mechanisms

The above analyses reveal that the main significance of the establishment of the MEP lies in the changes to authority that it engendered. The establishment of the MEP may also affect pollution control through the following two mechanisms.

First, this administrative reform is conducive to dealing with cross-regional pollution. Solutions for managing transboundary pollution are not yet mature in China. Therefore, local governments tend to free ride (Sigman, 2002; Duvivier and Xiong, 2013; Kahn et al., 2015). MEP establishment was the starting point for supplementing this shortcoming. In issuing the *Guiding Opinions of the Ministry of Environmental Protection on Preventing and Disposing Cross-Provincial Water Pollution Disputes*, the MEP highlighted (1) its strict control of new sources of pollution in upstream areas and acceleration of the green development of industries; (2) that new investments in upstream areas with serious pollution spillovers require permits from downstream areas; and (3) that cities and counties that fail to meet the key water pollution discharge total control indicators would be publicly announced.[6] At the request of the central government, many cross-regional pollution control projects have been constructed.[7] The central government's increasingly detailed and comprehensive treatment of cross-regional pollution is conducive to controlling it (Cao and Lv, 2013).

Second, the central government imposes effective pollution control incentives on local governments based on this reform. In the past, economic development was the main pursuit of local governments. They had strong incentives to relax environmental regulations to make full use of natural resources to develop the economy, thereby negatively affecting the environment (Li and Zhou, 2005; Wu et al., 2014). In 1990s, China adopted a graded monitoring system in which environmental data were aggregated from the local to the central governments. This allowed local governments to hide pollution by reporting revised environmental data. After the establishment of the MEP, the central government added the Environmental Monitoring Department and worked hard to establish its own monitoring stations for direct monitoring. Since 2008, the MEP has issued a list of companies that produce excessive pollutant emissions or that are involved in environmental accidents. This has made it impossible for local governments to cover up these companies' violations for economic reasons. Environmental conditions have also become one of the main assessment indicators of local governments, thus keeping them from the race to the bottom. In summary, the establishment of the MEP has made the monitoring data obtained by the central government more credible and has strengthened local governments' pollution control incentives.

[3] According to the Ministry of Finance of the People's Republic of China, the proportion of the central government's environmental protection expenditure increased from 0.28% in 2007 to 2.1% in 2008.

[4] The agreement between the provinces of Anhui and Zhejiang offers an example. The compensation areas in Anhui refused to invest over 10 billion yuan from polluting companies, and the water quality at the boundary demonstrated continuous improvement.

[5] If a region does not complete the tasks of energy conservation and emission reduction, the government in this region will be disqualified from the annual evaluation and the leader was prevented from promotion. Furthermore, new high-energy consumption or heavy-pollution projects in the region will be prohibited.

[6] See http://www.gov.cn/gzdt/2008-07/11/content_1042367.htm.

[7] For example, the cities of Wuxi and Huzhou cooperate to manage the Taihu Lake Basin, and the provinces of Guangdong and Guangxi cooperate to manage the Kyushu Basin.

3. Data and estimation strategy

3.1. Data and variable definitions

3.1.1. Key variables

Given the issues of human manipulation, omission, and vulnerability to meteorological changes in China's official environmental data (Ghanem and Zhang, 2014), we obtain air pollution raster data from Columbia University's Socioeconomic Data and Applications Center. Using ArcGIS software, we extract the annual $PM_{2.5}$ concentrations recorded for provinces in China from 2001 to 2015 as the core pollution indicator. Such data are commonly used in the research of pollution problems (Chang et al., 2016). In view of the various types of pollution in China, such as water pollution, soil pollution, and air pollution, we use the entropy method to combine the industrial emissions of wastewater, waste gas, solid waste, smoke, and dust into a comprehensive pollution index (CPI) for robustness checks. We collect the data from the *China Environmental Statistics Yearbook*.

Referring to Qi et al. (2014), we describe the degree of environmental decentralization between the central and local governments based on staff changes in environmental protection departments. The EDI are expressed as follows:

$$\mathrm{EDI_{it}} = \left[\frac{\mathrm{LE_{it}}/\mathrm{POP_{it}}}{\mathrm{NE_t}/\mathrm{POP_t}}\right] \times \left(1 - \frac{\mathrm{GDP_{it}}}{\mathrm{GDP_t}}\right) \tag{1}$$

The $EDI_{i,t}$ represents the degree of environmental decentralization of province i in year t, and provinces with larger EDI have a higher degree of environmental decentralization. LE_{it} and NE_t represent the staff population of environmental departments in province and nationwide (including in both the central and local governments), respectively. $POP_{it}(POP_t)$ and $GDP_{it}(GDP_t)$ denote the total population and the gross domestic product, respectively. We compile data on the staff at different levels of environmental protection agencies from the *China Environmental Statistics Yearbook.*

3.1.2. Other variables

In the baseline regression, we use local development variables and climate variables as the control variables, including innovation, fiscal decentralization, industrial structure, openness, economic development, pollution fee, urbanization, and rainfall. We construct the rainfall data from provincial yearbooks and the *Water Resources Bulletin* and obtain the other data from the *China City Statistical Yearbook*.

We introduce the control variables above for the following reasons. Innovation is one of the main factors affecting pollution emissions (Muazu and Xuan, 2021). The higher the level of fiscal decentralization, the greater the effort expended by local governments to achieve economic growth (Fell and Kaffine, 2014). Regarding the industrial structure variable, primary and secondary industries emit more pollution than tertiary industries (Zheng et al., 2020). Considering the spillover effect, the advanced technology brought about by foreign direct investment may reduce the intensity of emissions (Hille et al., 2019). As such, we introduce the openness variable. Environmental Kuznets curves have shown that emission intensity may change with economic development (Miah et al., 2010). Environmental regulations, measured by the pollution fee variable, are the main channels through which governments control pollution (Zhou et al., 2019). Urbanization affects pollution emissions through infrastructure and energy consumption (Wang et al., 2018). Finally, as rain may clean the air (He et al., 2020), we introduce the rainfall variable.

When considering pollution at the boundary, we use water quality indicators reported by the automatic water quality monitoring site in China. As air pollution at the boundary is affected by many factors, it may cause estimation bias.[8] The Chinese government has established monitoring stations in some river basins and lakes and has reported water quality indicators weekly since 2004. Some monitoring sites are located at the borders of provinces, providing natural experimental data to test this mechanism (Kahn et al., 2015). The weekly reports include four water quality indicators: pH value, dissolved oxygen (DO) concentration, chemical oxygen demand (COD), and ammonia nitrogen (NH_3–N) concentration. According to the *First National Pollution Census Announcement*, COD and NH_3–N are the main pollutants emitted by industry and the main sources of pollution in China's rivers. However, local governments reduced COD emissions to comply with central government regulations during the Eleventh Five-Year Plan period (Li et al., 2015), which has had a significant impact on COD concentration (Li et al., 2015).[9] Therefore, we do not consider COD. Instead, we use the NH_3–N and DO concentrations as pollution indicators. A greater NH_3–N concentration indicates more serious water pollution, whereas a greater DO concentration indicates better water quality. The data come from the water quality automatic monitoring weekly reports from 2004 to 2015. The relevant control variables include the pollution fee, fiscal decentralization, economic development, rainfall, river length, and official promotion variables. We also control for year- and season-fixed effects. The data on official promotion come from the China Stock Market & Accounting Research (CSMAR) database.

We use the absolute frequency and relative frequency of environmental-related vocabulary in local government work reports to measure the pollution control efforts of local governments (Chen et al., 2016). In general, the total length of the annual government work reports of local governments is stable. The higher the frequency of words related to the environment, the greater the efforts made by local governments towards pollution control. When testing the mechanism of local environmental governance, we introduce the following control variables: innovation, fiscal decentralization, industrial structure, openness, economic development, and urbanization. Table 1 provides all of the variable definitions.

3.2. Descriptive statistics

Table 2 reports the descriptive statistics for all of the variables. The difference between the maximum EDI value (2.236) and the minimum EDI value (0.405) is 1.831, and the fluctuation is significant (standard deviation is 34.8%). This indicates a considerable difference in environmental decentralization in each region. In the interest of space, the descriptive features of the other variables are not explained.

The data in this study are constructed from three sources, namely the yearbooks, the *Water Resources Bulletin*, and the CSMAR database. The yearbooks are compiled by the National Bureau of Statistics of China. They have been used extensively in research (Zhang et al., 2017; Wen et al., 2019; Cheng et al., 2020). The *Water Resources Bulletin* is compiled by the Water Supplies Bureau of the local governments, which describes the rainfall, water quality, and total water resources of provinces and cities. As these bulletins follow the standards published by the MEP, the data between regions are comparable. The CSMAR database is specially designed for academia. It contains more than 10 series of data, such as stock market, company, and industry data, which have been widely used in the literature (Lyon et al., 2013; Gao et al., 2015; Chen and Keefe, 2020).

[8] Most of China's air pollution monitoring stations are located in built-up areas rather than at the borders, and the spillover of air pollution is greatly affected by factors such as wind speed, wind direction, and season (He et al., 2020).

[9] The Eleventh Five-Year Plan spanned 2006 to 2010, including 2008, the year in which the MEP was established.

Table 1
Definition of variables

Variable	Definition of variables
Panel A: Baseline estimation	
EDI	the degree of environmental decentralization.
Pollution	the logarithm of the annual average of $PM_{2.5}$ concentration; unit: $\mu g/m^3$.
CPI	Comprehensive Pollution Index calculated from the industrial emission of wastewater, waste gas, solid waste, smoke and dust using the entropy method.
Innovation	the logarithm of enterprise patent acceptance quantity; unit: pcs.
Fiscal decentralization	the logarithm of the proportion of fiscal revenue to fiscal expenditure in local budgets.
Industrial structure	the proportion of secondary industry output value to GDP; unit: percent.
Openness	the logarithm of the proportion of import and export to GDP.
Economic development	the logarithm of per capita GDP; unit: ten thousand CNY per person.
Pollution fee	the logarithm of pollution fees; unit: ten thousand CNY.
Urbanization	the logarithm of the proportion of the non-agricultural population to the total population.
Rainfall	the logarithm of annual average rainfall in each province; unit: mm.
Panel B: Mechanism of pollution at the borders	
DO	the concentration of dissolved oxygen; unit: mg/L.
NH_3–N	the concentration of ammonia nitrogen; unit: mg/L.
River length	the logarithm of river length; unit: km.
Official promotion	the dummy variable is 1 in the year of promotion and the previous year, otherwise 0.
Panel C: Mechanism of local environmental governance	
Absolute frequency	the logarithmic of the frequency of environmental-related vocabulary in local government work report; unit: pcs.
Relative frequency	the percentage of the environmental-related vocabulary in local government work report; unit: percent.

Table 2
Descriptive statistics.

Variable	Obs	Mean	S.D	Min	Max
EDI	450	0.953	0.348	0.405	2.236
Pollution	450	3.277	0.626	1.569	4.415
Innovation	450	7.918	1.707	3.689	11.949
Fiscal decentralization	450	0.758	0.468	0.157	3.351
Industrial structure	450	0.464	0.078	0.197	0.590
Openness	450	2.295	0.969	0.400	4.506
Economic development	450	5.374	0.782	3.396	6.975
Pollution fee	450	10.358	1.057	6.764	12.531
Urbanization	450	3.859	0.291	3.198	4.495
Rainfall	450	6.647	0.635	4.609	7.783
DO	21,395	7.518	3.051	0.010	86.600
NH_3–N	21,593	1.3129	3.074	0.010	92.600
River length	21,593	6.046	1.435	2.664	8.764
Official promotion	22,403	0.248	0.432	0	1
Absolute frequency	420	3.648	0.477	1.946	4.737
Relative frequency	420	0.804	0.306	0.252	2.048

3.2. Estimation strategy

With the negative externalities of pollution gradually drawing attention, China began to implement administrative reforms to better solve the pollution problem (Li and Zhang, 2019). In 2008, China officially established the MEP and clarified its main responsibilities. This reform has caused different changes in EDI in different regions. Considering this reform to be a quasi-natural experiment, we use a DiD design to estimate whether changes in the degree of environmental decentralization are conducive to solving pollution problems.

The DiD method has been widely used to evaluate the effects of policies or reforms. It was initially used by Ashenfelter and Card (1985) to study the impact of Comprehensive Employment and Training Act (CETA) training on the income structure of students. It has since been applied in fields related to the economy, finance, and the environment (Andersson, 2019; Guceri and Liu, 2019; She et al., 2019). The idea of the DiD method is that a certain policy or reform exerts different influences on different samples. Correspondingly, the affected samples are from the treatment group, and the unaffected samples are from the control group. The effect of this shock can be obtained by subtracting the average change in the post-shock treatment group from the average change in the control group. Dividing the treatment group and the control group via a binary variable indicates whether they were shocked.

In this study, the reform shocked all of the samples, so the textbook DiD strategy no longer works. For credibility, we use both of the above-mentioned means of expansion. Using previous studies as references (Wang and Kong, 2016; Zhang et al., 2019), the standard DiD specification grouped by shock intensity is expressed as follows:

$$\mathrm{Pollution_{it}} = \alpha_0 + \alpha_1 \mathrm{Post_t} + \alpha_2 \mathrm{Treat_i} + \alpha_3 \mathrm{Post_t} \times \mathrm{Treat_i} + \alpha \mathrm{X_{it}} + \alpha_f + \varepsilon_{i,t}, \tag{2}$$

where $Pollution_{it}$ is the pollution level of province i in year t. $Post_t$ is a dummy for the years post-MEP establishment (i.e., after 2008), which equals 1 for 2008 and after and 0 otherwise. $Treat_i$ is used to distinguish between the treatment and control groups, where it equals 1 for the treatment group and 0 for the control group. In our DiD specification, all of the provinces with EDI values below (above) the mean EDI value are categorized as the control (treatment). is the key variable used to identify the policy effect. X_{it} denotes a series of control variables. α_f is the area-fixed effect. $\varepsilon_{i,t}$ is the error term.

Considering that MEP establishment affects the EDI of all provinces, we also introduce a continuous DiD design to capture the effect of this reform and thereby enhance the credibility of the results. Referring to previous studies (Bai and Jia, 2016; Chen et al., 2018), we specify the continuous DiD design as follows:

$$\mathrm{Pollution_{it}} = \beta_0 + \beta_1 \mathrm{Post_t} + \beta_2 \mathrm{EDI_{it}} + \beta_3 \mathrm{Post_t} \times \mathrm{EDI_{it}} + \beta \mathrm{X_{it}} + \alpha_f + \varepsilon_{i,t}. \tag{3}$$

We adopt two versions (equations (2) and (3)) and reached the same conclusion for both of them, which demostrates that our conclusion is independent of the version in use. We also introduce area-fixed effects, which can to some extent avoid the impact of unobserved omitted variables. Therefore, we improve the model in terms of both credibility and accuracy.

Before conducting the baseline estimation, we must check whether the outcome variables of the treat group and the control group were paralleled before this reform. The parallel trend test equations under the standard DiD design and the continuous DiD design are expressed as follows:

$$\mathrm{Pollution_{it}} = \varnothing_0 + \varnothing_T \sum_{T=2001}^{2007} \mathrm{Year_T} \times \mathrm{Treat_i} + \varnothing \mathrm{X_{it}} + \alpha_f + \varepsilon_{i,t}, \tag{4}$$

$$\mathrm{Pollution_{it}} = \theta_0 + \theta_T \sum_{T=2001}^{2007} \mathrm{Year_T} \times \mathrm{EDI_{it}} + \theta \mathrm{X_{it}} + \alpha_f + \varepsilon_{i,t}, \tag{5}$$

where $Year_T$ is a year dummy. Specifically, $Year_{2001}$ equals 1 for 2001 and 0 for other years; $Year_{2002}$ to $Year_{2007}$ are defined in the same way. Only the samples before this policy are retained. Other variables are the same as described above. If the coefficient $\varnothing_T$ or θ_T is not statistically significant, the outcome variables of these two groups were paralleled before the reform. To capture the dynamic effects of the establishment of the MEP, we refer to the dynamic effect test of Serfling (1986) to create a series of year dummy variables. The test equations under the standard DiD design and the continuous DiD design are expressed as follows:

$$\mathrm{Pollution_{it}} = \omega_0 + \omega_T \sum_{t=-3}^{3} \mathrm{Post(t)_i} + \omega \mathrm{X_{it}} + \alpha_f + \varepsilon_{i,t}, \tag{6}$$

$$\text{Pollution}_{it} = \rho_0 + \rho_T \sum_{t=-3}^{3} \text{Post\_EDI}(t)_i + \rho X_{it} + \alpha_f + \varepsilon_{i,t}. \quad (7)$$

In Eq. (6), $Post(-t)_i$ equals 1 for the treatment group sample in the t-th year before the reform, and $Post(t)_i$ equals 1 for the treatment group sample in the t-th year after the reform, where t is 0, 1, 2, or 3. t equals 0 for the year in which the reform was carried out. Eq. (7) represents the continuous model. The value of $Post\_EDI(t)_i$ equals the EDI value in the t-th year, and t is the same as in Eq. (6).

4. Empirical results

4.1. Baseline results

Columns 1 and 2 of Table 3 report the baseline regression results of Eq. (2). Columns 3 and 4 report the baseline regression results of Eq. (3). We include all of the controls in columns 2 and 4. The coefficients on the interaction term are negative and statistically significant in all specifications, indicating that the decrease in the degree of environmental decentralization symbolized by the establishment of the MEP has significantly reduced pollution levels. Under the standard DiD design, for every 1-point decrease in the degree of environmental decentralization, the pollution level decreases by 15%. In contrast, under the continuous DiD design, a 1-point decrease in the degree of environmental decentralization results in a 19.5% reduction in the pollution level. Our conclusion that decentralization leads to environmental degradation is consistent with the conclusion of Sigman (2005). Whereas Sigman (2005) placed more emphasis on the downstream losses caused by free riding, the present study is not limited in this way.

Consistent with the findings of Huang (2017), we find that fiscal decentralization leads to more emissions in China. Under the soft constraints of the budget system, the government's efforts to catch up under the promotion incentive will significantly reduce local environmental quality. A 1% increase in openness can reduce pollution by approximately 13%, mainly due to the spillover effects of foreign firms on local firms and the introduction of green technologies (Letchumanan and Kodama, 2000; Eskeland and Harrison, 2003), which can improve the environment of the host country. We also find that a pollution fee does not contribute to the improvement of the environment as expected. Conversely, it significantly increases the pollution level under the standard DiD design. Under the continuous DiD design, the coefficient on the pollution fee variable remains positive but is not significant. Firms that pay pollution fees tend to evade their responsibility to uphold ecological protection efforts, thereby trading environmental well-being for performance (Zhang et al., 2015).

Table 3
Effect of environmental decentralization on pollution.

	Standard DiD design		Continuous DiD design	
	(1)	(2)	(3)	(4)
Post×Treat (or Post×EDI)	−0.190**	−0.150*	−0.174*	−0.195**
	(-1.997)	(-1.883)	(-1.736)	(-2.151)
Post	0.138***	−0.071	0.228**	0.056
	(2.689)	(-0.918)	(2.168)	(0.476)
Treat (or EDI)	−0.195***	−0.040	−0.278***	−0.076
	(-2.776)	(-0.578)	(-3.650)	(-0.859)
Innovation		0.227***		0.225***
		(8.670)		(8.236)
Fiscal decentralization		0.158***		0.168***
		(3.170)		(3.449)
Industrial structure		0.252		0.146
		(0.632)		(0.367)
Openness		−0.131***		−0.133***
		(-3.132)		(-3.045)
Economic development		−0.279***		−0.289***
		(-2.960)		(-3.068)
Urbanization		0.185		0.212
		(0.969)		(1.085)
Pollution fee		0.057		0.074*
		(1.519)		(1.870)
Rainfall		0.043		0.031
		(1.127)		(0.754)
_cons	3.551***	1.653***	3.793***	1.637**
	(69.509)	(2.603)	(41.447)	(2.553)
Area fixed effects	yes	yes	yes	yes
Observations	450	450	450	450
Adjusted R^2	0.448	0.608	0.430	0.607

4.2. Parallel trend test

The parallel trend assumption is needed to ensure the internal validity of the DiD designs. It requires the difference between the treatment and control groups to be constant over time in the absence of reform. We use two methods to test the parallel trend assumption. First, while keeping the settings of the treatment and control groups constant, we keep only the samples before 2008. We then run the regressions in Eqs. (4) and (5), respectively, which can indicate whether the treatment and control group samples demonstrate significant differences in the pollution level pre-MEP establishment. Columns 1 and 2 of Table 4 show the regression results for the standard DiD design and the continuous DiD design, respectively. None of the coefficients on the interaction terms ($Year \times Treat$ and $Year \times EDI$) show any statistical power. Fig. 2 provides the regression coefficients from Eqs. (4) and (5) and their 95% confidence intervals. It reveals that none of the coefficients are significantly different from 0, suggesting that both the treatment and control groups follow similar time trends before 2008.

Columns 3 and 4 of Table 4 report the results of the dynamic effect tests. None of the coefficients on $Post(-3)$, $Post(-2)$, and $Post(-1)$are statistically significant, confirming the parallel trend. Meanwhile, right after the establishment of the MEP, the coefficients on the year dummy variables become statistically significant. Under the standard DiD design, these coefficients are stable at approximately −0.06. In the continuous DiD design, these coefficients become statistically significant and gradually increase in magnitude. The results reveal that the effect of the establishment of MEP on pollution may increase over time.

4.3. Robustness checks

4.3.1. DiD estimation combined with propensity score matching

To ensure that sample selection does not give rise to estimation bias in the baseline results, we use propensity score matching to match the treatment group and the control group and then perform the DiD estimation. Many studies have only used one matching method (Wang et al., 2019). However, different matching methods may yield different control groups. To avoid reaching a conclusion that only holds in a single way, we consider three matching methods: nearest neighbor matching, kernel matching, and radius matching. Before matching, the propensity score must be obtained using the dummy variable (*Treat*) as the interpreted variable and the selected control variables as the explanatory variable for the logit regression. As such, the continuous DiD design is not suitable for estimation in this part of the study. To conserve space, we do not report the detailed matching process. Table 5 reports the final DiD results. Regardless of which method is used for matching, the coefficients on $Post \times Treat$ are negative and statistically significant, consistent with the baseline results.

4.3.2. Time placebo tests

To avoid the influence of unobserved factors on the results, we set a series of false reform times and perform the DiD estimation again (Abadie et al., 2015). If the coefficient on the interaction term remains statistically significant, the baseline results are caused by other unobserved factors, rather than the establishment of the MEP. We assume the years of MEP establishment to be 2005, 2006, and 2007 and adjust the value of the *Post* variable accordingly. Table 6 reports the results. Columns 1 to 3 show the results under the standard DiD design. Columns 4

Table 4
Results of parallel tread test and event study.

Variable	Parallel trend test		Variable	Event study	
	Standard DiD	Continuous DiD		Standard DiD	Continuous DiD
	(1)	(2)		(3)	(4)
$Year_{2001}\times$ Treat (or $Year_{2001}\times$ EDI)	0.063	−0.004	Post(-3) (or Post_EDI (-3))	−0.063	−0.176
	(0.421)	(-0.029)		(-1.392)	(-1.184)
$Year_{2002}\times$ Trear(or $Year_{2002}\times$ EDI)	−0.022	−0.040	Post(-2) (or Post_EDI (-2))	−0.033	−0.103
	(-0.175)	(-0.301)		(-0.760)	(-0.673)
$Year_{2003}\times$ Treat (or $Year_{2003}\times$ EDI)	0.122	0.084	Post(-1) (or Post_EDI (-1))	−0.050	−0.185
	(1.058)	(0.644)		(-1.524)	(-1.327)
$Year_{2004}\times$ Treat (or $Year_{2004}\times$ EDI)	−0.152	−0.010	Post(0) (or Post_EDI (0))	−0.069**	−0.263**
	(-1.159)	(-0.076)		(-2.076)	(-2.044)
$Year_{2005}\times$ Treat (or $Year_{2005}\times$ EDI)	−0.011	0.110	Post(1) (or Post_EDI (1))	−0.064*	−0.414***
	(-0.074)	(0.794)		(-1.890)	(-2.904)
$Year_{2006}\times$ Treat (or $Year_{2006}\times$ EDI)	0.061	0.202	Post(2) (or Post_EDI (2))	−0.065**	−0.418***
	(0.388)	(1.329)		(-2.183)	(-3.083)
$Year_{2007}\times$ Treat (or $Year_{2007}\times$ EDI)	−0.001	0.129	Post(3) (or Post_EDI (3))	−0.069**	−0.502***
	(-0.006)	(0.891)		(-2.223)	(-3.341)
_cons	1.622	2.215**	_cons	4.018***	0.939
	(1.579)	(1.979)		(5.397)	(0.945)
Control variables	yes	yes	Control variables	yes	yes
Area fixed effects	yes	yes	Area fixed effect	yes	yes
Observations	210	210	Observations	210	210
Adjusted R^2	0.583	0.587	Adjusted R^2	0.506	0.599

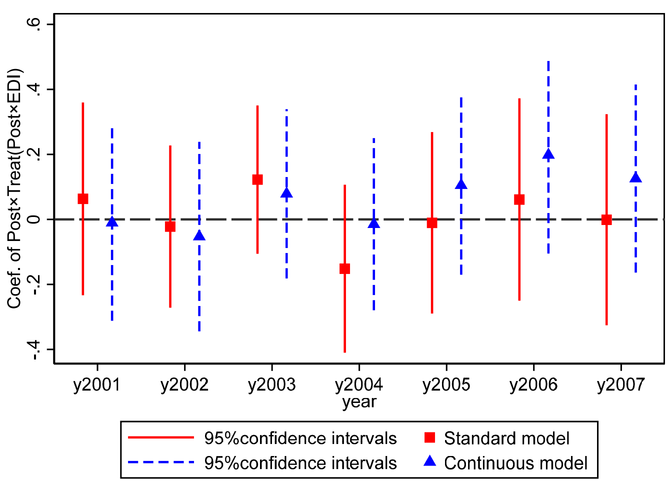

Fig. 2. Parallel trend test.

Table 5
Results of DiD estimation combined with PSM method.

	nearest neighbor matching	kernel matching	radius matching
	(1)	(2)	(3)
Post×Treat	−0.150*	−0.297**	−0.209**
	(-1.668)	(-2.222)	(-2.263)
Treat	−0.066	−0.182*	−0.021
	(-0.902)	(-1.850)	(-0.276)
Post	−0.094	0.142**	−0.112
	(-0.975)	(2.269)	(-1.366)
_cons	1.432**	3.329***	0.713
	(2.152)	(68.611)	(0.989)
Control variables	yes	yes	yes
Area fixed effects	yes	yes	yes
Observations	344	353	398
Adjusted R^2	0.664	0.085	0.579

to 6 show the results under the continuous DiD design. The coefficients on *Post* × *Treat* and *Post* × *EDI* are not statistically significant, suggesting that the environment condition of the treatment group has not been improved after the false reform time. This demonstrates the robustness of the baseline results.

4.3.3. Other tests

A policy evaluation should try to exclude the impact of other events. Beijing hosted the 29th Olympic Games in 2008, making it a year of great significance in Chinese history. To meet the green requirements of the Olympics, a series of environmental policies were introduced, such as the closure or relocation of heavily polluting enterprises and the implementation of single and double travel. These measures have significantly improved the environment in Beijing and Tianjin (Wang and Zhang, 2014). To avoid this interference, we exclude the Beijing and Tianjin samples and perform the DiD estimation again. If the coefficient on the interaction term is no longer significant, the baseline results are not robust. Columns 1 and 2 of Table 7 report the results.

In addition, the $PM_{2.5}$ concentration is used for the explanatory variables in the baseline regression, indicating that the establishment of the MEP effectively improves the air quality in provinces with high environmental decentralization. However, China's environmental pollution involves various aspects, such as water pollution and soil pollution. If our results are only established under the air pollution index, it would be hard to guarantee their credibility. To comprehensively measure the pollution level, we use the entropy method to combine industrial wastewater discharge, industrial waste gas emissions, industrial smoke (powder) dust emissions, and industrial solid waste emissions into a CPI. Columns 3 and 4 of Table 7 report the results of the DiD estimation using the CPI as an alternative indicator of pollution.

In columns 1 and 2, the coefficients on the interaction term are −0.123 and −0.208, respectively. These values are roughly the same as in the baseline results, indicating that the implementation of environmental policies during the 2008 Olympic Games does not affect our conclusions. In the tests of the alternative pollution indicator, the coefficient on the interaction term remains significantly negative. This indicates that MEP establishment not only significantly affects air pollution but also significantly reduces other aspects of water, solid, and other pollution. The above series of robustness tests confirms that the baseline results of this study are robust.

Table 6
Results of time placebo tests.

Variable	Standard DiD design			Continuous DiD design		
	2005	2006	2007	2005	2006	2007
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treat (or Post × EDI)	−0.124	−0.115	−0.133	−0.175	−0.116	−0.118
	(-1.528)	(-1.354)	(-1.466)	(-1.509)	(-0.966)	(-0.931)
Treat (or EDI)	−0.044	−0.045	−0.024	−0.070	−0.083	−0.067
	(-0.609)	(-0.584)	(-0.286)	(-0.692)	(-0.777)	(-0.580)
Post	0.055	0.201***	0.265***	0.164	0.256**	0.317**
	(0.715)	(2.783)	(3.788)	(1.269)	(1.969)	(2.365)
_cons	1.756***	1.891***	1.966***	1.720**	1.862***	1.929***
	(2.774)	(3.023)	(3.155)	(2.503)	(2.718)	(2.825)
Control variables	yes	yes	yes	yes	yes	yes
Area fixed effects	yes	yes	yes	yes	yes	yes
Observations	450	450	450	450	450	450
Adjusted R^2	0.605	0.609	0.614	0.604	0.606	0.611

Table 7
Results of other tests.

Variable	Exclusion of other policies		Alternative pollution indicator	
	Standard DiD	Continuous DiD	Standard DiD	Continuous DiD
	(1)	(2)	(3)	(4)
Post × Treat (or Post × EDI)	−0.123*	−0.208**	−0.012*	−0.020*
	(-1.716)	(-2.561)	(-1.684)	(-1.706)
Treat (or EDI)	−0.050	−0.078	0.012**	0.009
	(-0.728)	(-0.988)	(2.397)	(1.184)
Post	−0.024	0.127	0.003	0.017*
	(-0.325)	(1.193)	(0.471)	(1.679)
_cons	1.245**	1.107*	0.236***	0.234***
	(2.012)	(1.797)	(3.126)	(3.111)
Control variables	yes	yes	yes	yes
Area fixed effects	yes	yes	yes	yes
Observations	420	420	450	450
Adjusted R^2	0.661	0.662	0.318	0.316

5. Mechanisms

5.1. Pollution at the borders

In this section, we shed light on the channels underlying the link between environmental centralization and pollution. We first test the mechanism of pollution at the borders. Table 8 provides the results.

Table 8
Mechanism of pollution at the borders.

Variable	Standard DiD design		Continuous DiD design	
	NH_3–N	DO	NH_3–N	DO
	(1)	(2)	(3)	(4)
Post × Treat (or Post × EDI)	−1.820***	0.658***	−2.456***	0.934***
	(-7.487)	(5.749)	(-7.914)	(5.911)
Treat (or EDI)	2.315***	−0.626***	2.946***	−0.627***
	(8.517)	(-5.204)	(9.207)	(-3.856)
Post	1.292***	0.590***	3.069***	−0.051
	(10.745)	(6.986)	(10.976)	(-0.310)
_cons	22.846***	9.776***	21.006***	10.099***
	(21.669)	(18.079)	(21.138)	(18.319)
Control variables	yes	yes	yes	yes
Season fixed effects	yes	yes	yes	yes
Area fixed effects	yes	yes	yes	yes
Observations	21,593	21,395	21,593	21,395
Adjusted R^2	0.094	0.177	0.091	0.178

Notes: The control variables include official promotion, rainfall, fiscal decentralization, pollution fee, economic development, river length, and industrial structure.

Columns 1 and 2 (3 and 4) report the estimates of the standard (continuous) DiD design. The results under both designs show a significant decrease in NH_3–N and an increase in DO. Therefore, the environmental centralization caused by the establishment of MEP is effective in controlling border pollution.

Li et al. (2015) also studied pollution control at the borders, but from the perspective of environmental policy. They found that water quality was significantly improved after such policy implementation, but this improvement was less than that arising from MEP establishment in this study. That is, compared with environmental policies, the adjustment of environmental systems may be more important when it comes to improving border pollution.

5.2. Local environmental governance

Since the establishment of the MEP, energy saving and emission reduction have been included in the assessment of local officials' performance. The central government's direct monitoring of local pollutants has also been reinforced. Hence, this reform may affect local environmental welfare by enhancing environmental governance incentives. We select the absolute frequency and relative frequency of the environmentally related vocabulary used in local government work reports to comprehensively measure local governments' effort to protect the environment. Government work reports serve as good research materials (Hou and Yang, 2016; Shi et al., 2019). These reports cover a wide range of fields, such as public health (Jin, 2016) and the environment (Shi et al., 2019). It must be noted that this study differs from most research in one obvious way: we not only study the absolute level of vocabulary (Hou and Yang, 2016) but also include the relative level. Relative frequency (relative to absolute frequency) can eliminate the impact of the total number of words in government work reports. Thus, regression results with relative frequency as the outcome variable are more convincing. Table 9 shows the effect of environmental decentralization on local environmental governance.

Columns 1 and 3 (2 and 4) show the regression results with absolute (relative) frequency as the dependent variable. The coefficients on the interaction term in three of the four regressions are significantly positive. The relative frequency increases by 11.6% under the standard DiD design and by 16.4% under the continuous DiD design. This suggests that since the establishment of the MEP, the environmental governance incentives of local governments have been strengthened and have become conducive to reducing pollution.

6. Discussion and conclusion

Starting with the allocation of environmental powers, the effectiveness of environmental centralization is verified by the establishment of the MEP in China, which represents the foundation of its environmental

Table 9
Mechanism of local environmental governance.

Variable	Standard DiD design		Continuous DiD design	
	Absolute frequency	Relative frequency	Absolute frequency	Relative frequency
	(1)	(2)	(3)	(4)
Post × Treat (or Post × EDI)	0.119	0.116**	0.283***	0.164***
	(1.616)	(2.461)	(2.620)	(3.182)
Treat (or EDI)	−0.084	−0.073	−0.160	−0.108
	(-1.126)	(-1.331)	(-0.913)	(-1.046)
Post	0.349***	0.119**	0.130	0.007
	(5.061)	(2.441)	(1.140)	(0.104)
Control variables	yes	yes	yes	yes
Area fixed effects	yes	yes	yes	yes
Observations	420	420	420	420
Adjusted R^2	0.541	0.540	0.548	0.540

Notes: The control variables include innovation, fiscal decentralization, industrial structure, economic development, and urbanization.

efforts. Based on this, we build an indicator based on the number of staff in the environmental department and then examine the effect of environmental centralization on pollution control and the associated mechanism. The results show that environmental centralization can help improve China's environment. Furthermore, since the administrative reform, the central government has organized neighboring areas to reduce pollution at the borders and strengthened local governments' incentives for pollution control.

This study is not without limitations. For example, it suffers from data limitations. As a result, we are only able to obtain the number of environmental protection staff at the provincial level, despite China having a multi-level government structure in which cities, counties, and townships are below provinces. The EDIcan only work at the provincial level, which may limit the scope of our analysis. Additionally, we only consider water pollution between jurisdictions. However, the spillover effect of air pollution is more obvious (Cai et al., 2016a; Feng et al., 2020). Identifying factors such as wind direction and wind speed may allow for a more comprehensive examination of the influence of a centralized government on the spillover effect of air pollution.

The study has meaningful real-world implications. Environmental regulations are important means used by governments to protect the environment, but they are not the only means. Whether environmental policies can effectively constrain local governments and companies depends in part on the allocation of environmental powers among governments at all levels. We recognize the need to adjust the environmental management system, promote the convergence of environmental powers to higher-level governments, and gradually form a vertical system (Zhang et al., 2018). As economic growth remains the main goal of local governments in developing countries (Chen et al., 2018), strengthening only the political and economic incentives can effectively restrain local government behavior. Thus, environmental assessments should be added to the promotion decisions of local officials.

Accurate monitoring data are essential for policy making and for evaluating the efforts of local governments. Non-standard local environmental monitoring methods and imperfect systems may lead to large deviations in environmental data (Batterbury and Fernando, 2006). Therefore, standard monitoring technology and operating specifications are required nationwide.

Finally, environmental protection organizations, especially monitoring organizations, should be independent at all levels of government to avoid political constraints that might distort environmental protection behaviors and effects.

In future research, we plan to consider the impact of environmental decentralization at the enterprise level. Environmental regimes may lead to different corporate behaviors. For example, it is easier for companies to lobby lower-level governments (Esty, 1996). We can also consider the impact of environmental regimes on unexpected environmental factors, such as energy consumption and foreign direct investment.

CRediT authorship contribution statement

Weibing Li: Conceptualization, Methodology, Software, Writing – original draft, Writing – review & editing, Supervision. **Yongwen Yang:** Data curation, Software, Visualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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